LA-8633-MS

UC-66e

Issued: January 1981

Meteorological Analysis for Fenton Hill, 1979

Sumner Barr
S. Kerry Wilson

DISCLAIMER

This book was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

METEOROLOGICAL ANALYSIS FOR FENTON HILL, 1979

by

Sumner Barr and S. Kerry Wilson

ABSTRACT

Three years of meteorological data have been collected at the Fenton Hill site to establish a local climatic baseline, transport and diffusion climatology, and an initial site for an eventual Valles Caldera meteorological network. Tower-based wind and temperature data at 15 m above ground were supplemented during 1979 with precipitation, humidity and pressure measurements, and a limited program of upper winds. Preliminary analysis of the data has been made to identify major topographic and meteorological driving forces affecting the local climatic variations on diurnal and seasonal time scales. The site is quite high and exposed enough that external influences such as gradient wind flow and thunderstorms tend to dominate over purely local driving forces in determining climate. Locally generated wind circulations are identifiable at night but tend to be weak and sporadic. The presence of topographic obstacles on the 10- to 100-km scale is observed in the winds.

I. INTRODUCTION

Three years of meteorological data have been collected at the Fenton Hill Hot Dry Rock geothermal site in the Jemez mountains in support of environmental studies. One planned purpose of the data is to establish a local climatic baseline against which possible induced climate changes may be evaluated. Also, it is important to have estimates of the wind field to maintain the capability to assess the transport of airborne pollutants that may emanate from the drilling and heat-exchange operations. In view of proposed expansion of a geothermal industry in the Valles Caldera area, good estimates of the meteorological structure will be invaluable in identifying the correct sources of trace gases such as H_2S . An additional requirement for meteorological data is in engineering design and operational safety questions (e.g. temperature, pressure, wind chill, structural wind loading). As industrial activity increases in the Valles Caldera, the Fenton Hill meteorological site will become an important baseline station in a network of observation sites. With these considerations in mind we have conducted an analysis on the first three years of record and designed an expanded measurement system that will allow us to address a broader range of questions. Sections II and III of this report describe the analyses of the existing data set and Section IV describes the updated meteorological system.

II. SURFACE METEOROLOGICAL SURVEY

Winds and temperature have been recorded since 1976 by means of a mechanical weather station mounted on a 15-m tower. Pressure and humidity have been recorded during 1979 in an instrument shelter at 1.5 m above ground. Figure 1 shows the locations of the tower and shelter on the Fenton Hill site. Supplemental upper air data were collected using pilot balloons on an approximately weekly case study basis.

Figure 2 shows the Fenton Hill location in relation to the entire Jemez mountain complex. The site is at 2651-m elevation on a relatively flat knoll that separates two major canyons. The fetch from the southeast through west to northwest is quite unobstructed although winds with significant northerly or easterly components must pass over or around

topography above 3300 m. Several questions of topographic influence enter into the analysis of wind observations. If we can determine some topographic driving influences such as drainage or obstacle flow phenomena, then we have a basis for estimating the region of representativeness of a single wind station and a basis for estimating air trajectories and potential pollution receptor locations.

Figures 3a-3d show wind roses for each season compiled from the three year record. Winter has a west to northwest predominance that gradually gives way through spring to a southerly maximum occurrence in summer. Autumn and Spring wind roses are quite similar. Figure 4 shows a breakdown of the winter wind rose by diurnal periods. The most distinctive difference from midday to nocturnal conditions is the growth of a northerly maximum in the moderate speed range. The summer nighttime winds reflect a dominant component from the southeast that gives way to southerly and westerly dominance during the day accompanied by an increase in wind speed as shown in Fig. 5. A secondary maximum occurrence of northerly flow at night is similar to the winter night case.

We can attempt to identify the major driving forces for the winds and to distinguish diurnal and seasonal differences in driving force that relate to the variations in winds. The daytime winds generally reflect the large-scale pressure gradient flow which exhibits westerly dominance throughout the year in northern New Mexico. The winter northwesterly and summer southerly components are consistent with the seasonal pressure patterns. The situation at night becomes somewhat more complicated. On some nights local temperature differences on sloping surfaces produce local circulations that are generally shallow and frequently are decoupled from wind fields that exist above by virtue of very stable vertical temperature lapse rates that strongly damp turbulent momentum transfer. On other nights the mechanical turbulence generated by the interaction of the large scale winds with the ground is sufficient to overwhelm the locally driven winds. An intermediate phenomenon is the addition of two approximately equal wind vectors to produce an airflow between the purely local wind and a synoptically forced flow. An important part of the study of topographically complex sites is to identify the major forcing functions and the conditions under which they interact. Variables affecting the balance

include large-scale wind speed and direction, cooling parameters including cloud cover, atmospheric moisture, terrain surface orientation, moisture, and snow cover. Two features of the wind roses reflect local wind patterns on perhaps two different scales. First, the northerly wind in both winter and summer lines up with a weakly defined topographic channel between the San Pedro mountains and Redondo Peak and also with San Antonio creek canyon which borders the site. The other characteristic feature is an easterly component that exists at night but is seldom observed during the day. The easterly wind appears to be vectorially added to the existing gradient flow producing resultant winds that include northeast and southeast directions. The source of the easterly component could be a slope wind induced by Redondo Peak or the initial stages of drainage flow into one of two canyons that border the site on the northeast and south sides, respectively.

Another presentation that is useful for describing diurnal wind patterns is the seasonal composite hodograph, shown in Fig. 6a-6d. Vector mean winds for each clock-hour in the sample are calculated and plotted as the tail of the vector with its head at the origin. The resulting hodograph reflects a systematic variation of the wind throughout the diurnal period. The seasonal grouping tends to combine winds that result from an assortment of external transient forces such as synoptic gradient flows. This grouping therefore will yield the diurnal variation about a prevailing wind. Since large-scale winds are generally lighter in summer the hodographs for that season are more likely to reflect locally driven wind patterns.

The winter hodograph indicates winds from the northwest quadrant through the nocturnal period with westerly components near midday. This is fully consistent with the wind rose format. The diurnal hodograph for spring is very similar to winter in its general shape except that daytime winds are slightly stronger with a distinct southwesterly component. The progression of the wind vectors through the day is in the sense of turning clockwise or veering with time.

The summer pattern is quite different. Southwest winds during the day change somewhat abruptly to easterly at about sunset. An equally rapid transition to the daytime regime occurs near sunrise. The fall season also shows a binary preference for northwest flow at night and slightly stronger west to southwest wind in the day with a fairly rapid transition between the two regimes.

In an effort to relate surface based wind observations to an indicator of the large-scale synoptic flow, a pair of one month samples, representative of winter and summer seasons, were selected and scatter diagrams, Figs. 7a-7d were made. The 700 millibar (approximately 3 km above sea level) wind direction from the Albuquerque radiosondes at 0500 MST and 1700 MST were chosen to represent the free air wind direction near the altitude of Fenton Hill and concurrent surface winds at Fenton Hill are plotted against this indicator. The winter afternoon shows a good correlation between large-scale flow and the surface winds. At night, the correlation remains good except for two departures. There is a tendency for the Fenton Hill winds to be shifted about 30° to the north from the free air wind direction. This could be the result of channeling between Redondo Peak and the San Pedro mountains. The other exception is a small cluster of points showing northeasterly surface flow with west to northwest wind in the free atmosphere. The easterly component may reflect a de-coupled surface wind of local origin. The summer nocturnal winds are essentially uncorrelated with the free air wind directions (Fig. 7c). The correlation between daytime wind directions is not much higher. Apparently, some nonpersistent local effect (e.g., thermal convection) has an influence on the local surface winds.

Tables I-III present selected statistics on temperature and precipitation for the three year record of data.

III. WINDS ALOFT SURVEY

Surface meteorological data tends to be influenced by local topographic and vegetative features and one good way to assess the usefulness of a measurement point for estimating trajectories that cover an area about the point is to obtain vertical soundings above that location.

TABLE I
FENTON HILL METEOROLOGICAL DATA FOR 1976

	Temperatures(°C)							Precipitation(mm)		
	Average			Extremes				Total	Greatest Day	Date
	Daily Max.	Daily Min.	Monthly	Highest	Date	Lowest	Date			
January	0	-10	-6	8	28	-22	2	4.8	3.3	24
February	1	- 6	-3	8	1	-16	21	41.4	11.4	13
March	1	- 7	-3	9	25	-17	5	17.5	4.3	28
April	6	- 2	2	12	10	-13	17	21.1	10.4	15
May	12	2	7	18	15	-6	8	45.0	21.8	6
June	19	8	14	26	28	2	15	6.1	3.5	6
July	19	10	14	25	10	4	24	74.9	18.8	21
August	18	9	13	23	12	4	2	69.1	15.8	18
September	14	6	10	22	4	-1	28	45.7	10.7	20
October	7	0	3	18	10	-7	19	4.8	3.3	23
November	2	-2	-1	12	6	-23	28	17.5	17.5	27
December	1	-7	-4	8	3	-13	6	8.6	5.3	31
Year	8.3	0.1	3.8	26	6/28	-23	11/28	356.5	18.8	7/21

TABLE II
FENTON HILL METEOROLOGICAL DATA FOR 1977

	Temperatures(°C)							Precipitation(mm)		
	Average			Extremes				Total	Greatest Day	Date
	Daily Max.	Daily Min.	Monthly	Highest	Date	Lowest	Date			
January	-3	-9	-8	10	19	-20	9	48.5	11.4	1
February	2	-7	-3	9	20	-16	26	17.0	8.9	2
March	0	-8	-4	9	8	-15	3	16.0	8.9	4
April	7	-1	3	14	8	-12	4	45.3	12.2	3
May	12	2	8	20	31	-2	15	25.4	16.8	12
June	21	11	16	26	17	6	7	6.4	2.5	24
July	20	11	15	26	30	5	9	76.2	17.5	4
August	20	11	15	26	2	7	12	113.8	33.8	15
September	15	8	11	22	8	3	12	26.9	13.0	12
October	12	4	7	17	4	-3	11	8.1	4.1	6
November	2	-2	1	11	3	-17	9	25.4	15.0	6
December	0	-6	-4	8	11	-17	20	14.5	4.1	28
Year	9.0	1.3	4.8	26	6/17	-20	1/9	423.5	33.8	8/15

TABLE III
FENTON HILL METEOROLOGICAL DATA FOR 1978

	Temperatures(°C)							Precipitation(mm)		
	Average			Extremes				Total	Greatest Day	Date
	Daily Max.	Daily Min.	Monthly	Highest	Date	Lowest	Date			
January ¹										
February	-1	-8	-6	9	22	-22	18	49.5	16.0	11
March	3	-3	0	14	31	-12	15	35.1	10.4	2
April	8	0	4	14	24	-6	10	3.8	2.0	8
May	11	3	7	20	30	-7	7	71.6	38.1	2
June	20	9	15	26	24	3	3	8.9	3.8	28
July	19	11	17	26	15	7	24	26.7	6.4	22
August ²	14	7	13	23	12	4	30	49.5	16.5	24
September	15	6	10	21	4	-1	21	46.5	25.4	24
October ²	10	4	9	17	1	-1	14	48.0	21.6	21
November ³	-	-	-	-	-	-	-	95.3	27.9	4
December ³	-	-	-	-	-	-	-	74.4	18.5	6
Year								509.3	38.1	5/2

- ¹ Missing
² Not complete
³ Less than 66% data

Local influences that dominate winds near the ground tend to diminish with altitude leaving a greater spatial coherence of wind measurements at several hundred meters above ground. A program of soundings for winds aloft was established to address several questions including:

- how well do Albuquerque upper winds represent the free air winds (above boundary domination) at Fenton Hill?
- how representative are surface based tower measurements for plume transport estimates from Fenton Hill site?
- are there consistencies in the structure of the wind profiles that can lead to an understanding of the basic phenomena governing the local wind climatology?

The technique required to measure wind aloft is a labor intensive manual method so the data set is smaller than the surface observations. A series of soundings were made on an approximately weekly basis when weather permitted between February and September, 1979. A summary of the soundings is given in Table IV. Surface wind directions are well correlated with the winds aloft. The root mean square departure between the two sets of observations is only 26.6 degrees. Winds at three altitudes were chosen for comparison with Albuquerque winds at the equivalent height. The levels, 3.0, 3.5 and 4.0 km above sea level (MSL) represent elevations near the major ridge tops in the area, near the highest peak, and well above topographic obstacles, respectively. The standard deviation of the departures between Fenton Hill and Albuquerque wind directions decreases with altitude, suggesting some terrain effect at 3.0 km that is significantly reduced by 4.0 km MSL. The mean and standard deviation of departures are given in Table V.

TABLE IV
SUMMARY OF WINDS ALOFT SURVEY

key: wind speed/wind direction (degrees)		3.0 km	3.5 km	4.0 km	FH Surface Wind	ABQ 700 MB Wind
7 FEB	FH	15.7/308	24.0/305	24.0/305	6.9/301	
	WR	2.0/75	5.5/280			
	ABQ	14.5/295	19.0/310	19.5/305		15.4/325
1 MAR	FH	8.0/185	13.0/205	16.0/225	2.7/201	
	WR					
	ABQ	13.0/195	16.0/205	17.5/215		
8 MAR	FH	5.0/295	18.0/290	13.0/295	7.0/277	
	WR	9.5/285	8.0/295	15.0/295		
	ABQ	9.5/290	9.5/285	9.0/285		9.77/290
28 MAR	FH	7.0/225			1.7/232	
	WR	5.0/255				
	ABQ	9.5/220	11.5/210	17.0/205		9.5/220
5 APR	FH	3.5/310	2.0/010	6.0/310	2.4/269	
	WR	2.0/100	4.0/275			
	ABQ	5.5/300	7.5/280	8.5/275		5.4/290
11 APR	FH	17.0/300			8.6/285	
	WR	7.0/290	10.0/280			
	ABQ	14.0/290	19.0/280	14.0/285		13.5/290
18 APR	FH	12.0/180	7.0/240	12.0/220	4.8/202	
	WR	11.0/205	16.0/200	8.0/210		
	ABQ	10.5/195	11.0/200	13.0/230		9.4/195
25 APR	FH	9.0/295	10.5/295	9.0/295	4.4/304	
	WR	10.0/275	6.0/280	6.5/295		
	ABQ	15.5/310	15.5/300	15.5/295		12.5/290
16 MAY	FH	6.5/245	5.5/210	4.0/225	3.4/203	
	WR	5.0/230	5.5/220	9.0/195		
	ABQ	8.0/225	8.0/230	10.5/240		6.3/295
22 MAY	FH	3.0/55	4.0/350	5.5/300	4.2/92	
	WR	2.0/80	3.5/50	6.5/15		
	ABQ	3.0/345	4.0/330	7.0/315		3.1/345
30 MAY	FH	6.0/245	8.0/215	11.5/240	4.1/267	
	WR	13.5/215	11.0/225	10.0/245		
	ABQ	7.0/230	7.5/240	7.5/250		6.7/230
6 JUN	FH	6.6/302	7.1/298	7.2/310	4.6/249	
	WR					
	ABQ	8.4/302	11.1/316	12.1/320		8.0/310
13 JUN	FH	3.1/162	4.4/220	3.9/260	3.1/203	
	WR	8.2/203	8.3/221	8.6/243		
	ABQ	8.7/189	6.5/177	6.0/205		8.0/180
27 JUN	FH	6.7/275	6.3/284	8.4/294	2.5/242	
	WR					
	ABQ	1.7/207	1.2/270	2.68/301		1.0/185
5 JUL	FH	2.9/100	4.4/184	3.2/175	3.6/104	
	WR	3.2/200				
	ABQ	4.0/241	4.0/195	3.4/200		4.0/221
2 AUG	FH	7.1/270	3.5/327	6.1/337	5.0/267	
	WR	4.4/22	3.6/17	4.6/11		
	ABQ	4.6/357	5.7/333	7.7/319		4.0/5
22 AUG	FH	7.1/270	3.5/327	6.1/337	5.0/267	
	WR	1.5/160	4.1/288			
	ABQ	6.3/301	6.8/304	8.1/297		7.0/305
6 SEP	FH	2.9/160	2.7/170	1.7/192	3.6/147	
	WR					
	ABQ	3.0/199	3.0/158	3.0/142		3.0/190
13 SEP	FH	5.8/194	4.1/291	16.6/287	2.8/191	
	WR					
	ABQ	6.5/243	9.0/291	9.4/308		6.0/265
26 SEP	FH	5.1/180	6.9/185	2.3/277	3.1/192	
	WR					
	ABQ	5.7/203	5.2/227	9.1/260		4.0/195

TABLE V

MEAN AND STANDARD DEVIATION OF DEPARTURES BETWEEN SIMULTANEOUS PAIRS
OF WIND DIRECTION OBSERVATIONS

<u>Observation Pair</u>	<u>Mean, degrees</u>	<u>Standard Deviation, degrees</u>
Fenton Hill 3.0 km ABQ 3.0 km	12.5	54.5
Fenton Hill 3.5 km ABQ 3.5 km	-0.5	40.8
Fenton Hill 4.0 km ABQ 4.0 km	1.5	28.1
Fenton Hill surface Fenton Hill 3.0 km	-2.0	26.6

IV. METEOROLOGICAL MEASUREMENT SYSTEM

An updated tower-based meteorological observation and recording system has been designed and recently installed at the Fenton Hill site. In addition to wind direction and speed and temperature at two levels (4 m and 20 m); precipitation, humidity, and pressure are recorded hourly on magnetic tape cassettes. The new system will run concurrently with the existing tower for a comparison period of six months in order to document changes in the data that may arise from differences in location, instrumentation, recording, and reduction methods.

Analysis software is currently being prepared that will hopefully lead to a product that is useful for climate documentation, pollutant transport estimation and HDR operations support as well as establishing a baseline for a future Valles Caldera meteorological network. Preliminary analysis products will be distributed to interested parties and we will solicit reactions on their utility prior to setting up final analysis procedures.

Fig. 1. Plan view of Fenton Hill site.

Fig. 2. Topographic diagram of the Valles Caldera area, including Fenton Hill.

Fig. 3a.

Fig. 3b.

Fig. 3c.

Fig. 3d.

Fig. 3. Seasonal wind roses, all hours combined.

WINTER

Fig. 4a.

Fig. 4b.

Fig. 4c.

Fig. 4d.

Fig. 4. Wind roses for four periods of the day, winter.

SUMMER

Fig. 5a.

Fig. 5b.

Fig. 5c.

Fig. 5d.

Fig. 5. Wind roses for four periods of the day, summer.

Fig. 6. Diurnal hodographs for each season of the year. Wind blows from the plotted curve to the origin.

Fig. 7a. Scatter diagram relating surface (2.7 km MSL) wind direction at Fenton Hill to the 700 mb (3 km MSL) level winds from the Albuquerque upper air sounding. Comparisons are for winter mornings.

Fig. 7b. Scatter diagram relating surface (2.7 km MSL) wind direction at Fenton Hill to the 700 mb (3 km MSL) level winds from the Albuquerque upper air sounding. Comparisons are for winter afternoons.

Fig. 7c. Scatter diagram relating surface (2.7 km MSL) wind direction at Fenton Hill to the 700 mb (3 km MSL) level winds from the Albuquerque upper air sounding. Comparisons are for summer mornings.

Fig. 7d. Scatter diagram relating surface (2.7 km MSL) wind direction at Fenton Hill to the 700 mb (3 km MSL) level winds from the Albuquerque upper air sounding. Comparisons are for summer afternoons.